The ILCOR Paediatric Task Force included expert reviewers from Africa, Asia, Australia, Asia, Europe, North America, and South America. These experts reviewed 45 topics related to paediatric resuscitation. Topics were selected from previous recommendations (the ECC Guidelines 2000), emerging science, and newly identified issues. Some well-established topics without controversies or new evidence (e.g. adenosine for the treatment of supraventricular tachycardia (SVT)) are not included in this document.

Evidence-based worksheets on some topics were prepared and discussed but are not included here because there was insufficient evidence (e.g. fibrinolytics in cardiac arrest, securing the tracheal tube in children, use of impedance threshold device in children, sodium bicarbonate for prolonged resuscitation attempts) or because no new evidence was found (e.g. evaluation of capillary refill, ventilation before naloxone, delayed volume resuscitation in trauma, use of hypertonic saline in shock).

The following is a summary of the most important changes in recommendations for paediatric resuscitation since the last ILCOR review in 2000. The scientific evidence supporting these recommendations is summarised in this document:

- Emphasis on the quality of CPR is increased: “Push hard, push fast, minimise interruptions; allow full chest recoil, and don’t hyperventilate.”
  - Recommended chest compression–ventilation ratio:
    - for one lay rescuer: 30:2;
    - for healthcare providers performing two-rescuer CPR: 15:2.
  - Either the two- or one-hand technique is acceptable for chest compressions in children.
  - One initial shock followed by immediate CPR for attempted defibrillation instead of three stacked shocks.
- Biphasic attenuated shocks with an automated external defibrillator (AED) are acceptable for children >1 year.
- Routine use of high-dose adrenaline is no longer recommended.
- Either cuffed or uncuffed tracheal tubes are acceptable in infants and children.
- Exhaled CO2 monitoring is recommended for confirmation of tracheal tube placement and during transport.
- Consider induced hypothermia for patients who remain comatose following resuscitation.
- Emphasis is increased on intravascular (intravenous (IV) and intraosseous (IO)) rather than tracheal administration of drugs.

The ILCOR Paediatric Task Force re-evaluated the definitions of newborn, infant, child, and adult. These definitions are somewhat arbitrary but are important because some recommendations for treatment differ according to patient size and the most likely aetiology of arrest. The distinction between child and adult victims has been de-emphasised by the recommendation of a universal compression–ventilation ratio for lay rescuers and the same chest compression technique for lay rescuers of children and adults. Some differences in treatment recommendations remain between the...
newborn and infant and between an infant and child, but those differences are chiefly linked to resuscitation training and practice. They are noted below.

Identified knowledge gaps in paediatric resuscitation include:

- Sensitive and specific indicators of cardiac arrest that lay rescuers and healthcare providers can recognise reliably.
- Effectiveness of aetiology-based versus age-based resuscitation sequences.
- The ideal ratio of chest compressions to ventilations during CPR.
- Mechanisms to monitor and optimise quality of CPR during attempted resuscitation.
- Best methods for securing a tracheal tube.
- Clinical data on the safety and efficacy of automated external defibrillators (AEDs).
- Clinical data on the safety and efficacy of the laryngeal mask airway (LMA) during cardiac arrest.
- The benefits and risks of supplementary oxygen during and after CPR.
- Clinical data on antiarrhythmic and pressor medications during cardiac arrest.
- The use of fibrinolytics and anticoagulants in cardiac arrest.
- Use of emerging technologies for assessment of tissue perfusion.
- Predictors of outcome from cardiac arrest.

Initial steps of CPR

The ECC Guidelines 2000 recommended that lone rescuers of adult victims of cardiac arrest phone the emergency medical services (EMS) system and get an AED ("call first") before starting CPR. The lone rescuer of an unresponsive infant or child victim was instructed to provide a brief period of CPR before leaving the victim to phone for professional help and an AED ("call fast"). These sequence differences were based on the supposition that cardiac arrest in adults is due primarily to ventricular fibrillation (VF) and that a hypoxic-ischaemic mechanism is more common in children. But this simplistic approach may be inaccurate and may not provide the ideal rescue sequence for many victims of cardiac arrest. Hypoxic-ischaemic arrest may occur in adults, and VF may be the cause of cardiac arrest in up to 7% to 15% of infants and children. Resuscitation results might be improved if the sequence of lay rescuer CPR actions, (i.e. the priority of phoning for professional help, getting an AED, and providing CPR) is based on the aetiology of cardiac arrest rather than age.

The pulse check was previously eliminated as an assessment for the lay rescuer. There is now evidence that healthcare professionals may take too long to check for a pulse and may not determine the presence or absence of the pulse accurately. This may lead to interruptions in chest compressions and affect the quality of CPR.

Experts reviewed the data on the technique of rescue breathing for infants and the two-thumb-encircling hands versus two-finger chest compression techniques for infants.

One of the most challenging topics debated during the 2005 Consensus Conference was the compression–ventilation ratio. The scientific evidence on which to base recommendations was sparse, and it was difficult to arrive at consensus. Evidence was presented that the ratio should be higher than 5:1, but the optimal ratio was not identified. The only data addressing a compression–ventilation ratio greater than 15:2 came from mathematical models. The experts acknowledged the educational benefit of simplifying training for lay rescuers (specifically one-rescuer CPR) by adopting a single ratio for infants, children, and adults with the hope that simplification might increase the number of bystanders who will learn, remember, and perform CPR. On this basis experts agreed that this single compression–ventilation ratio should be 30:2. Healthcare providers typically will be experienced in CPR and practice it frequently. This group of experienced providers will learn two-person CPR, and for them the recommended compression–ventilation ratio for two rescuers is 15:2.

Some laypeople are reluctant to perform mouth-to-mouth ventilation. For treatment of cardiac arrest in infants and children, chest compressions alone are better than no CPR but not as good as a combination of ventilations and compressions. In the past one-handed chest compressions were recommended for CPR in children. A review of the evidential basis for this recommendation was conducted. From an educational standpoint, we agree that it will simplify training to recommend a single technique for chest compressions for children and adults.

Activating emergency medical services and getting the AED

Consensus on science. Most cardiac arrests in children are caused by asphyxia (LOE 4).3–6
Observational studies of non-VF arrests in children show an association between bystander CPR and intact neurological outcome (LOE 4).6—8 Animal studies show that in asphyxial arrest, chest compressions plus ventilation CPR is superior to either chest compression-only CPR or ventilation-only CPR (LOE 6).9

Observational studies of children with VF report good (17% to 20%) rates of survival after early defibrillation (LOE 4).5,6,10 The merits of “call first” versus “call fast” CPR sequences have not been studied adequately in adults or children with cardiac arrest of asphyxial or VF etiologies. Three animal studies (LOE 6)9,11,12 show that even in prolonged VF, CPR increases the likelihood of successful defibrillation, and seven adult human studies (LOE 7)13—19 document improved survival with the combination of CPR with minimal interruptions in chest compression and early defibrillation.

Treatment recommendation. A period of immediate CPR before phoning emergency medical services (EMS) and getting the AED (“call fast”) is indicated for most paediatric arrests because they are presumed to be asphyxial or prolonged. In a witnessed sudden collapse (e.g. during an athletic event), the cause is more likely to be VF, and the lone rescuer should phone for professional help and get the AED (when available) before starting CPR. Rescuers should perform CPR with minimal interruptions in chest compressions until attempted defibrillation.

In summary, the priorities for unwitnessed or non-sudden collapse in children are as follows:

• Start CPR immediately.
• Activate EMS/get the AED.

The priorities for witnessed sudden collapse in children are as follows:

• Activate EMS/get the AED.
• Start CPR.
• Attempt defibrillation.

Pulse check

Consensus on science. Ten studies (LOE 220,21; LOE 422—24; LOE 527; LOE 628,29) show that lay rescuers23,25,30 and healthcare providers31,32—34 show that rescuers are often unable to accurately determine the presence of a pulse within 10 s. Two studies in infants (LOE 5)48,49 of haemodynamic monitoring in infants receiving chest compressions showed higher systolic and diastolic arterial pressures in the two-thumb encircling hands technique compared with the two-finger technique.

Treatment recommendation. Lay rescuers should start chest compressions for an unresponsive infant or child who is not moving or breathing. Healthcare professionals may also check for a pulse but should proceed with CPR if they cannot feel a pulse within 10 s or are uncertain if a pulse is present.

Ventilations in infants

Consensus on science. One LOE 5 study and 10 LOE 7 reports assessed a mouth-to-nose ventilation technique for infants. The LOE 5 study13 is an anecdotal report of three infants ventilated with mouth-to-nose technique. The LOE 7 reports describe postmortem anatomy,43 physiology of nasal breathing,45—47 related breathing issues,48,49 and measurements of infants’ faces compared with the measurement of adult mouths.50—52 There is great variation in these measurements, probably because of imprecise or inconsistent definitions.

Treatment recommendation. There are no data to justify a change from the recommendation that the rescuer attempt mouth-to-mouth-and-nose ventilation for infants. Rescuers who have difficulty achieving a tight seal over the mouth and nose of an infant, however, may attempt either mouth-to-mouth or mouth-to-nose ventilation (LOE 5).53

Circumferential versus two-finger chest compressions

Consensus on science. Two manikin (LOE 6)44,45 and two animal (LOE 6)46,47 studies showed that the two thumb-encircling hands technique of chest compressions with circumferential thoracic squeeze produces higher coronary perfusion pressures and more consistently correct depth and force of compression than the two-finger technique.

Case reports (LOE 5)54,55 of haemodynamic monitoring in infants receiving chest compressions showed higher systolic and diastolic arterial pressures in the two-thumb encircling hands technique compared with the two-finger technique.

Treatment recommendation. The two thumb-encircling hands chest compression technique with thoracic squeeze is the preferred technique for two-rescuer infant CPR. The two-finger technique is recommended for one-rescuer infant CPR to facilitate rapid transition between compression and ventilation to minimize interruptions in chest compressions. It remains an acceptable alternative method of chest compressions for two rescuers.
One-versus two-hand chest compression technique

Consensus on science. There are no outcome studies that compare one-versus two-hand compressions of the chest in children. One (LOE 6) study reported higher pressures generated in child manikins using the two-hand technique to compress over the lower part of the sternum to a depth of approximately one-third the anterior-posterior diameter of the chest. Rescuers reported that this technique was easy to perform.

Treatment recommendation. Both the one- and two-hand techniques for chest compressions in children are acceptable provided that rescuers compress over the lower part of the sternum to a depth of approximately one-third the anterior-posterior diameter of the chest. To simplify education, rescuers can be taught the same technique (i.e. two-hand) for adult and child compressions.

Compression—ventilation ratio

Consensus on science. There are insufficient data to identify an optimal compression—ventilation ratio for CPR in children. Manikin studies (LOE 6) have examined the feasibility of compression—ventilation ratios of 15:2 and 5:1. Lone rescuers cannot deliver the desired number of chest compressions per minute at a ratio of 5:1. A mathematical model (LOE 7) supports compression—ventilation ratios higher than 5:1 for infants and children.

Two animal (LOE 6) studies show that coronary perfusion pressure, a major determinant of success in resuscitation, declines with interruptions in chest compressions. In addition, once compressions are interrupted, several chest compressions are needed to restore coronary perfusion pressure. Frequent interruptions of chest compressions (e.g. with a 5:1 compression—ventilation ratio) prolongs the duration of low coronary perfusion pressure. Long interruptions in chest compressions have been documented in manikin studies (LOE 6) and both in- and out-of-hospital adult CPR studies (LOE 7). These interruptions reduce the likelihood of a return of spontaneous circulation (LOE 7). Five animal (LOE 6) and one review (LOE 7) studies and one review suggest that ventilations are relatively less important in victims with VF or pulseless ventricular tachycardia (VT) cardiac arrest than in victims with asphyxia-induced arrest. But even in asphyxial arrest, few ventilations are needed to maintain an adequate ventilation-perfusion ratio in the presence of the low cardiac output (and, consequently low pulmonary blood flow) produced by chest compressions.

Treatment recommendation. For ease of teaching and retention, a universal compression—ventilation ratio of 30:2 is recommended for the lone rescuer responding to infants (for neonates see Part 7: “Neonatal Resuscitation”), children, and adults. For healthcare providers performing two-rescuer CPR, a compression—ventilation ratio of 15:2 is recommended. When an advanced airway is established (e.g. a tracheal tube, Combitube, or laryngeal mask airway (LMA)), ventilations are given without interrupting chest compressions.

Some CPR versus no CPR

Consensus on science. Numerous reports (LOE 5) and three retrospective studies of adult VF (LOE 7) and numerous animal studies of VF cardiac arrest (LOE 6) document survival of children after cardiac arrest when bystander CPR was provided. Bystander CPR in these reports included rescue breathing alone, chest compressions alone, or a combination of compressions and ventilations.

One prospective and three retrospective studies of adult VF (LOE 7) and numerous animal studies of VF cardiac arrest (LOE 6) document comparable long-term survival after chest compressions alone or chest compressions plus ventilations, and both techniques result in better outcomes compared with no CPR. In animals with asphyxial arrest (LOE 6), the more common mechanism of cardiac arrest in infants and children, best results are achieved with a combination of chest compressions and ventilations. But resuscitation with either ventilations only or chest compressions only is better than no CPR.

Treatment recommendation. Bystander CPR is important for survival from cardiac arrest. Trained rescuers should be encouraged to provide both ventilations and chest compressions. If rescuers are reluctant to provide rescue breaths, however, they should be encouraged to perform chest compressions alone without interruption.

Disturbances in cardiac rhythm

Evidence evaluation for the treatment of haemodynamically stable arrhythmias focused on vagal manoeuvres, amiodarone, and procainamide. There were no new data to suggest a change in the indications for vagal manoeuvres or procainamide. Several case series described the safe and effective
Part 6: Paediatric basic and advanced life support

use of amiodarone in children, but these studies involved selected patient populations (often with postoperative arrhythmias) treated by experienced providers in controlled settings. Although there is no change in the recommendation for amiodarone as a treatment option in children with stable arrhythmias, providers are encouraged to consult with an expert knowledgeable in paediatric arrhythmias before initiating drug therapy.

There is insufficient evidence to identify an optimal shock waveform, energy dose, and shock strategy (e.g., fixed versus escalating shocks, one versus three stacked shocks) for defibrillation. The new recommendation for the sequence of defibrillation in children is based on extrapolated data from adult and animal studies with biphasic devices, data documenting the high rates of success for first shock conversion of VF with biphasic waveforms, and knowledge that interruption of chest compressions reduces coronary perfusion pressure. Thus, a one-shock strategy may be preferable to the three-shock sequence recommended in the ECC Guidelines 2000.2 For further details, see Part 3: Defibrillation.

Many, but not all, AED algorithms have been shown to be sensitive and specific for recognising shockable arrhythmias in children. A standard AED (adult AED with adult pad-cable system) can be used for children older than about 8 years and weighing more than about 25 kg. Many manufacturers now provide a method for attenuating the energy delivered to make the AED suitable for smaller children (e.g., use of a pad-cable system or an AED with a key or switch to select a smaller dose).

Management of supraventricular tachycardias

If the child with SVT is haemodynamically stable, we recommend early consultation with a paediatric cardiologist or other physician with appropriate expertise. This recommendation is common for all of the SVT topics below.

Vagal manoeuvres for SVT

Consensus on science. One prospective (LOE 3)90 and nine observational studies (LOE 491; LOE 592,93; LOE 794–99) show that vagal manoeuvres are effective in terminating SVT in children. There are reports of complications from carotid sinus massage and application of ice to the face to stimulate the diving reflex (LOE 5).100,101 but virtually none from the Valsalva manoeuvre.

Treatment recommendation. The Valsalva manoeuvre and ice application to the face may be used to treat haemodynamically stable SVT in infants and children. When performed correctly, these manoeuvres can be initiated quickly and safely and without altering subsequent therapies if they fail.

Amiodarone for haemodynamically stable SVT

Consensus on science. One prospective (LOE 3)102 and 10 observational (LOE 5)103–105 studies show that amiodarone is effective for treating SVT in children. A limitation of this evidence is that most of the studies in children describe treatment for postoperative junctional ectopic tachycardia.

Treatment recommendation. Amiodarone may be considered in the treatment of haemodynamically stable SVT refractory to vagal manoeuvres and adenosine. Rare but significant acute side effects include bradycardia, hypotension, and polymorphic VT (LOE 5).106–108

Procainamide for haemodynamically stable SVT

Consensus on science. Experience with procainamide in children is limited. Twelve LOE 5109–111 and four LOE 6112–114 observational studies show that procainamide can terminate SVT that is resistant to other drugs. Most of these reports include mixed populations of adults and children. Hypotension following procainamide infusion results from its vasodilator action rather than a negative inotropic effect (LOE 5115,116; LOE 6117).

Treatment recommendation. Procainamide may be considered in the treatment of haemodynamically stable SVT refractory to vagal manoeuvres and adenosine.

Management of stable wide-QRS tachycardia

If a child with wide-QRS tachycardia is haemodynamically stable, early consultation with a paediatric cardiologist or other physician with appropriate expertise is recommended. In general, amiodarone and procainamide should not be administered together because their combination may increase risk of hypotension and ventricular arrhythmias.

Amiodarone

Consensus on science. One case series (LOE 5)118 suggests that wide-QRS tachycardia in children is
more likely to be supraventricular than ventricular in origin. Two prospective studies (LOE 3) and 13 case series (LOE 5) show that amiodarone is effective for a wide variety of tachyarrhythmias in children. None of these reports specifically evaluates the role of amiodarone in the setting of a stable, unknown wide-complex tachycardia.

Treatment recommendation. Wide-QRS tachycardia in children who are stable may be treated as SVT. If the diagnosis of VT is confirmed, amiodarone should be considered.

Procainamide for stable VT

Consensus on science. Twenty observational studies, primarily in adults, but including some children show that procainamide is effective in the treatment of stable VT.

Treatment recommendation. Procainamide may be considered in the treatment of haemodynamically stable VT.

Management of unstable VT

Amiodarone

Consensus on science. In small paediatric case series (LOE 3) and extrapolation from animal (LOE 4) and adult (LOE 7) studies, amiodarone is safe and effective for haemodynamically unstable VT in children.

Treatment recommendation. Synchronised cardioversion remains the treatment of choice for unstable VT. Amiodarone may be considered for treatment of haemodynamically unstable VT.

Paediatric defibrillation

For additional information about consensus on science and treatment recommendations for defibrillation (e.g. one versus three stacked shock sequences and sequence of CPR first versus defibrillation first), see Part 3: "Defibrillation."

Manual and automated external defibrillation

Consensus on science. The ideal energy dose for safe and effective defibrillation in children is unknown. Extrapolation from adult data (LOE 1) and paediatric animal studies (LOE 6) shows that biphasic shocks are at least as effective as monophasic shocks and produce less postshock myocardial dysfunction. One LOE 5 and one LOE 6 study show that an initial monophasic or biphasic shock dose of 2 J kg⁻¹ generally terminates paediatric VF. Two paediatric case series (LOE 5) report that doses >4 J kg⁻¹ (up to 9 J kg⁻¹) have effectively defibrillated children <12 years, with negligible adverse effects.

In five animal studies (LOE 6) large (per kilogram) energy doses caused less myocardial damage in young hearts than in adult hearts. In three animal studies (LOE 6) and one small paediatric case series (LOE 5), a 50-J biphasic dose delivered through a paediatric pad/cable system terminated VF and resulted in survival. One piglet (13–26 kg) study (LOE 6) showed that paediatric biphasic AED shocks (50/75/86 J) terminated VF and caused less myocardial injury and better outcome than adult AED biphasic shocks (200/300/360 J).

Treatment recommendation. The treatment of choice for paediatric VF/pulseless VT is prompt defibrillation, although the optimum dose is unknown. For manual defibrillation, we recommend an initial dose of 2 J kg⁻¹ (biphasic or monophasic waveform). If this dose does not terminate VF, subsequent doses should be 4 J kg⁻¹.

For automated defibrillation, we recommend an initial paediatric attenuated dose for children 1–8 years and up to about 25 kg and 127 cm in length. There is insufficient information to recommend for or against the use of an AED in infants <1 year. A variable dose manual defibrillator or an AED able to recognise paediatric shockable rhythms and equipped with dose attenuation are preferred; if such a defibrillator is not available, a standard AED with standard electrode pads may be used. A standard AED (without a dose attenuator) should be used for children >23 kg (about 8 years) and adolescent and adult victims.

Management of shock-resistant VF/pulseless VT

Amiodarone

Consensus on science. Evidence extrapolated from three (LOE 1) studies in adults (LOE 7 when applied to children) shows increased survival to hospital admission but not discharge when amiodarone is compared with placebo or lidocaine for shock-resistant VF. One study in children (LOE 1)
showed effectiveness of amiodarone for life-threatening ventricular arrhythmias.

**Treatment recommendation.** Intravenous amiodarone can be considered as part of the treatment of shock-refractory or recurrent VT/VF.

### Airway and ventilation

Maintaining a patent airway and ventilation are fundamental to resuscitation. Adult and animal studies during CPR suggest detrimental effects of hyper-ventilation and interruption of chest compressions. For children requiring airway control or ventilation for short periods in the out-of-hospital setting, bag-valve-mask (BVM) ventilation produces equivalent survival rates compared with ventilation with tracheal intubation.

The risks of tracheal tube misplacement, displacement, and obstruction are well recognized, and an evidence-based review led to a recommendation that proper tube placement and patency be monitored by exhaled CO2 throughout transport. A review also found that cuffed tracheal tubes could be used safely even in infants.

Following the return of spontaneous circulation from cardiac arrest, toxic oxygen by-products (reactive oxygen species, free radicals) are produced that may damage cell membranes, proteins, and DNA (reperfusion injury). There are no clinical studies in children outside the newborn period comparing different concentrations of inspired oxygen during and immediately after resuscitation, and it is difficult to differentiate sufficient from excessive oxygen therapy.

#### Bag-valve-mask ventilation

Consensus on science. One out-of-hospital paediatric randomised controlled study (LOE 1) showed in an EMS system with short transport times showed that BVM ventilation compared with tracheal intubation resulted in equivalent survival to hospital discharge rates and neurological outcome in children requiring airway control, including children with cardiac arrest and trauma.

One study in paediatric cardiac arrest (LOE 1) showed that BVM ventilation was as effective as tracheal intubation. Four studies in children with trauma (LOE 3) found no advantage of tracheal intubation over BVM ventilation.

**Treatment recommendation.** In the out-of-hospital setting with short transport times, BVM ventilation is the method of choice for children who require ventilatory support. When transport times are long, the relative benefit versus potential harm of tracheal intubation compared with BVM ventilation is uncertain. It is affected by the level of training and experience of the healthcare professional and the availability of exhaled CO2 monitoring during intubation and transport.

### Advanced airways

Advanced airways include the tracheal tube, the Combitube, and the LMA. Experts at the 2005 Consensus Conference reviewed the available evidence on use of the tracheal tube and LMA in infants and children. There were no data on use of the Combitube in this age group.

#### Cuffed versus uncuffed tracheal tubes

Consensus on science. One randomised controlled trial (LOE 2), three prospective cohort studies (LOE 3), and one cohort study (LOE 4) document no greater risk of complications for children <8 years when using cuffed tracheal tubes compared with uncuffed tubes in the operating room and intensive care unit.

Evidence from one randomised controlled trial (LOE 2) and one small, prospective controlled study (LOE 3) showed some advantage in cuffed over uncuffed tracheal tubes in children in the paediatric anaesthesia and intensive care settings, respectively.

**Treatment recommendation.** Cuffed tracheal tubes are as safe as uncuffed tubes for infants (except newborns) and children if rescuers use the correct tube size and cuff inflation pressure and verify tube position. Under certain circumstances (e.g. poor lung compliance, high airway resistance, and large glottic air leak), cuffed tracheal tubes may be preferable.

#### Laryngeal mask airway

Consensus on science. There are no studies examining the use of the LMA in children during cardiac arrest. Evidence extrapolated from paediatric anaesthesia shows a higher rate of complications with LMAs in smaller children compared with LMA experience in adults. The complication rate decreases with increasing operator experience (LOE 7). Case reports document that the LMA can be helpful for management of the difficult airway.
Treatment recommendation. There are insufficient data to support or refute a recommendation for the routine use of an LMA for children in cardiac arrest. The LMA may be an acceptable initial alternative airway adjunct for experienced providers during paediatric cardiac arrest when tracheal intubation is difficult to achieve.

Confirmation of tube placement

Exhaled CO₂

Consensus on science. Misplaced, displaced, or obstructed tracheal tubes are associated with a high risk of death. No single method of tracheal tube confirmation is always accurate and reliable. One study (LOE 3) showed that clinical assessment of tracheal tube position (observation of chest wall rise, mist in the tube, and auscultation of the chest) can be unreliable for distinguishing oesophageal from tracheal intubation.

In three studies (LOE 5), when a perfusing cardiac rhythm was present in infants >2 kg and children, detection of exhaled CO₂ using a colourmetric detector or capnometer had a high sensitivity and specificity for tracheal tube placement. In one study (LOE 5) during cardiac arrest, the sensitivity of exhaled CO₂ detection for tracheal tube placement was 85% and specificity 100%. Both with a perfusing rhythm and during cardiac arrest, the presence of exhaled CO₂ reliably indicates tracheal tube placement, but the absence of exhaled CO₂ during cardiac arrest does not prove tracheal tube misplacement.

Treatment recommendation. In all settings (i.e. prehospital, emergency departments, intensive care units, operating rooms), confirmation of tracheal tube placement should be achieved using detection of exhaled CO₂ in intubated infants and children with a perfusing cardiac rhythm. This may be accomplished using a colourmetric detector or capnometer. During cardiac arrest, if exhaled CO₂ is not detected, tube position should be confirmed using direct laryngoscopy.

Oesophageal detector device

Consensus on science. A study in the operating room (LOE 2) showed that the oesophageal detector device (EDD) was highly sensitive and specific for correct tracheal tube placement in children weighing >20 kg with a perfusing cardiac rhythm. There have been no studies of the EDD in children during cardiac arrest. A paediatric animal study (LOE 6) showed only fair results with the EDD, but accuracy improved with use of a larger syringe. The same animal study showed no difference when the tracheal tube cuff was either inflated or deflated.

Treatment recommendation. The EDD may be considered for confirmation of tracheal tube placement in children weighing >20 kg.

Confirmation of tracheal tube placement during transport

Consensus on science. Studies (LOE 1; LOE 7) have documented the high rate of inadvertent displacement of tracheal tubes during prehospital transport. There are no studies to evaluate the frequency of these events during intra- or inter-hospital transport.

Two studies (LOE 5) show that in the presence of a perfusing rhythm, exhaled CO₂ detection or measurement can confirm tracheal tube position accurately during transport. In two animal studies (LOE 6), loss of exhaled CO₂ detection indicated tracheal tube displacement more rapidly than pulse oximetry. On the basis of one case series (LOE 5), continuous use of colourmetric exhaled CO₂ detectors may not be reliable for long (>30 min) transport duration.

Treatment recommendation. We recommend monitoring tracheal tube placement and patency in infants and children with a perfusing rhythm by continuous measurement or frequent intermittent detection of exhaled CO₂ during prehospital and intra- and inter-hospital transport.

Oxygen

Oxygen during resuscitation

Consensus on science. Meta-analyses of four human studies (LOE 1) showed a reduction in mortality rates and no evidence of harm in newborns resuscitated with air compared with 100% oxygen (see Part 7: Neonatal Resuscitation). The two largest studies, however, were not blinded, so results should be interpreted with caution. Two animal studies (LOE 6) suggest that ventilation with room air may be superior to 100% oxygen during resuscitation from cardiac arrest, whereas one animal study (LOE 6) showed no difference.
Part 6: Paediatric basic and advanced life support

Treatment recommendation. There is insufficient information to recommend for or against the use of any specific inspired oxygen concentration during and immediately after resuscitation from cardiac arrest. Until additional evidence is published, we support healthcare providers’ use of 100% oxygen during resuscitation (when available). Once circulation is restored, providers should monitor oxygen saturation and reduce the inspired oxygen concentration while ensuring adequate oxygen delivery.

Vascular access and drugs for cardiac arrest

Vascular access can be difficult to establish during resuscitation of children. Review of the evidence showed increasing experience with IO access and resulted in a de-emphasis of the tracheal route for drug delivery. Evidence evaluation of resuscitation drugs was limited by a lack of reported experience in children. There was little experience with vasopressin in children in cardiac arrest and inconsistent results in adult patients. In contrast, there was a good study in children showing no benefit and possibly some harm in using high-dose adrenaline for cardiac arrest.

Routes of drug delivery

Intraosseous access

Consensus on science. Two prospective randomised trials in adults and children (LOE 3) and six other studies (LOE 4) document that IO access is safe and effective for fluid resuscitation, drug delivery, and blood sampling for laboratory evaluation.

Treatment recommendation. We recommend establishing IO access if vascular access is not achieved rapidly in any infant or child for whom IV drugs or fluids are urgently required.

Drugs given via tracheal tube

Consensus on science. One study in children (LOE 2), five studies in adults (LOE 2), and multiple animal studies (LOE 6) indicate that atropine, adrenaline, naloxone, lidocaine, and vasopressin are absorbed via the trachea. Administration of resuscitation drugs into the trachea results in lower blood concentrations than the same dose given intravascularly. Furthermore, animal studies (LOE 6) suggest that the lower adrenaline concentrations achieved when the drug is delivered by tracheal route may produce transient α1-adrenergic effects. These effects can be detrimental, causing hypotension, lower coronary artery perfusion pressure and flow, and reduced potential for return of spontaneous circulation.

Treatment recommendation. Intravascular, including IO, injection of drugs is preferable to administration by the tracheal route. The recommended tracheal dose of atropine, adrenaline, or lidocaine is higher than the vascular dose and is as follows:

- Adrenaline 0.1 mg kg⁻¹ (multiple LOE 6 studies).
- Lidocaine 2–3 mg kg⁻¹ (LOE 3) and multiple LOE 6 studies.
- Atropine 0.03 mg kg⁻¹ (LOE 2).

The optimal tracheal doses of naloxone or vasopressin have not been determined.

Drugs in cardiac arrest

Dose of adrenaline for cardiac arrest

Consensus on science. In four paediatric studies (LOE 2, 3), there was no improvement in survival rates and a trend toward worse neurological outcome after administration of high-dose adrenaline for cardiac arrest. A randomised, controlled trial (LOE 2) comparing high-dose with standard-dose adrenaline for the second and subsequent (“rescue”) doses in paediatric in-hospital cardiac arrest showed reduced 24-h survival rates in the high-dose adrenaline group. In subgroup analysis, survival rates in asphyxia and sepsis were significantly worse with high-dose rescue adrenaline.

Treatment recommendation. Children in cardiac arrest should be given 10 μg kg⁻¹ of adrenaline as the first and subsequent intravascular doses. Routine use of high-dose (100 μg kg⁻¹) intravascular adrenaline is not recommended and may be harmful, particularly in asphyxia. High-dose adrenaline may be considered in exceptional circumstances (e.g. β-blocker overdose).

Vasopressin in cardiac arrest

Consensus on science. Based on a small series of children (LOE 5), vasopressin given after adrenaline may be associated with return of spontaneous circulation after prolonged cardiac arrest. Animal data (LOE 6) indicate that a
combination of adrenaline and vasopressin may be beneficial. Adult data are inconsistent. Giving vasopressin after adult cardiac arrest (LOE 7)\(^{141–147}\) has produced improved short-term outcomes (e.g. return of spontaneous circulation or survival to hospital admission) but no improvement in neurologically intact survival to hospital discharge when compared with adrenaline.

**Treatment recommendation.** There is insufficient evidence to recommend for or against the routine use of vasopressin during cardiac arrest in children.

**Magnesium in cardiac arrest**

**Consensus on science.** The relationship between serum magnesium concentrations and outcome of CPR was analyzed in three studies in adults (LOE 3\(^{148}\), LOE 4\(^{149}\)) and one animal study (LOE 6).\(^{250}\) The first two studies indicated that a normal serum concentration of magnesium was associated with a higher rate of successful resuscitation, but it is unclear whether the association is causative. Six adult clinical studies (LOE 1\(^{251}\); LOE 2\(^{252–255}\); LOE 3\(^{256}\)) and one study in an adult animal model (LOE 6\(^{257}\)) indicated no significant difference in any survival end point in patients who received magnesium before, during, or after CPR.

**Treatment recommendation.** Magnesium should be given for hypomagnesaemia and torsades de pointes VT, but there is insufficient evidence to recommend for or against its routine use in cardiac arrest.

**Postresuscitation care**

**Postresuscitation care is critical to a favourable outcome.** An evidence-based literature review was performed on the topics of brain preservation and myocardial function after resuscitation from cardiac arrest. It showed the potential benefits of induced hypothermia on brain preservation, the importance of preventing or aggressively treating hyperthermia, the importance of glucose control, and the role of vasoactive drugs in supporting haemodynamic function.

**Ventilation**

**Hyperventilation**

**Consensus on science.** One study in cardiac arrest patients (LOE 3)\(^{258}\) and extrapolation from 12 other studies (LOE 6\(^{259}\); LOE 2\(^{260}\); LOE 3\(^{261–267}\); LOE 4\(^{268}\); LOE 5\(^{269,270}\)) suggest that hyperventilation may cause decreased venous return to the heart and cerebral ischaemia and may be harmful in the comatose patient after cardiac arrest.

**Treatment recommendation.** Hyperventilation after cardiac arrest may be harmful and should be avoided. The target of postresuscitation ventilation is normocapnia. Short periods of hyperventilation may be performed as a temporising measure for the child with signs of impending cerebral herniation.

**Temperature control**

**Therapeutic hypothermia**

**Consensus on science.** Immediately after resuscitation from cardiac arrest, children often develop hypothermia followed by delayed hyperthermia (LOE 5).\(^{271}\) Hypothermia (32 \(^\circ\)C–34 \(^\circ\)C) may be beneficial to the injured brain. Although there are no paediatric studies of induced hypothermia after cardiac arrest, support for this treatment is extrapolated from:

- Two prospective randomised studies of adults with VF arrest (LOE 1\(^{272}\); LOE 2\(^{273}\)).
- One study of newborns with birth asphyxia (LOE 2\(^{274}\)).
- Numerous animal studies (LOE 6) of both asphyxial and VF arrest.
- Acceptable safety profiles in adults (LOE 6)\(^{272,273}\) and neonates (LOE 7\(^{275–278}\) treated with hypothermia (32 \(^\circ\)C–34 \(^\circ\)C) for up to 72 h.

**Treatment recommendation.** Induction of hypothermia (32 \(^\circ\)C–34 \(^\circ\)C) for 12–24 h should be considered in children who remain comatose after resuscitation from cardiac arrest.

**Treatment of hyperthermia**

**Consensus on science.** Two studies (LOE 5)\(^{271,279}\) show that fever is common after resuscitation from cardiac arrest, and three studies (LOE 7)\(^{280–282}\) show that it is associated with worse outcome. Animal studies suggest that fever causes a worse outcome. One study (LOE 6)\(^{283}\) shows that rats resuscitated from asphyxial cardiac arrest have a worse outcome if hyperthermia is induced within the first 24 h of recovery. In rats with global ischaemic brain injury (which produces endogenous fever), prevention of fever with a nonsteroidal anti-inflammatory drug (NSAID) class of antipyretic attenuated neuronal damage (LOE 6).\(^{284,285}\)
Part 6: Paediatric basic and advanced life support 281

Treatment recommendation. Healthcare providers should prevent hyperthermia and treat it aggressively in infants and children resuscitated from cardiac arrest.

Haemodynamic support

Vasoactive drugs

Consensus on science. Two studies in children (LOE 5),286,287 multiple studies in adults (LOE 2288–290), and animal studies (LOE 6)291–293 indicate that myocardial dysfunction is common after resuscitation from cardiac arrest. Multiple animal studies (LOE 6)294–296 document consistent improvement in haemodynamics when selected vasoactive drugs are given in the post-cardiac arrest period. Evidence extrapolated from multiple adult and paediatric studies (LOE 7)297–302 of cardiovascular surgical patients with low cardiac output documents consistent improvement in haemodynamics when vasoactive drugs are titrated in the period after cardiopulmonary bypass.

Treatment recommendation. Vasoactive drugs should be considered to improve haemodynamic status in the post-cardiac arrest phase. The choice, timing, and dose of specific vasoactive drugs must be individualised and guided by available monitoring data.

Blood glucose control

Treatment of hypoglycaemia and hyperglycaemia

Consensus on science. Adults with out-of-hospital cardiac arrest and elevated blood glucose on admission have poor neurological and survival outcomes (LOE 7).203–205 In critically ill children, hypoglycaemia (LOE 5)206 and hyperglycaemia (LOE 5)207 are associated with poor outcome. It is unknown if the association of hyperglycaemia with poor outcome after cardiac arrest is causative or an epiphenomenon related to the stress response.

In critically ill adult surgical patients, (LOE 7)211 strict glucose control improves outcome, but there are currently insufficient data in children showing that the benefit of tight glucose control outweighs the risk of inadvertent hypoglycaemia.

Several adult and animal studies (LOE 6)212–216 and an adult clinical study (LOE 4)217 show poor outcome when glucose is given immediately before or during cardiac arrest. It is unknown if there is harm in giving glucose-containing maintenance fluids to children after cardiac arrest.

Hypoglycaemia is an important consideration in paediatric resuscitation because:

- Critically ill children are hypermetabolic compared with baseline and have increased glucose requirement (6–8 mg kg\(^{-1}\) min\(^{-1}\)) to prevent catabolism.
- The combined effects of hypoglycaemia and hypoxia/ischaemia on the immature brain (neonatal animals) appears more deleterious than the effect of either insult alone.318
- Four retrospective studies of human neonatal asphyxia show an association between hypoglycaemia and subsequent brain injury (LOE 4215,216; LOE 5217,218).

Treatment recommendation. Healthcare providers should check glucose concentration during cardiac arrest and monitor it closely afterward with the goal of maintaining normoglycaemia. Glucose-containing fluids are not indicated during CPR unless hypoglycaemia is present (LOE 7).219

Prognosis

One of the most difficult challenges in CPR is to decide the point at which further resuscitative efforts are futile. Unfortunately, there are no simple guidelines. Certain characteristics suggest that resuscitation should be continued (e.g. ice water drowning, witnessed VF arrest), and others suggest that further resuscitative efforts will be futile (e.g. most cardiac arrests associated with blunt trauma or septic shock).

Predictors of outcome in children

Consensus on science. Multiple studies in adults have linked characteristics of the patient or of the cardiac arrest with prognosis following in-hospital or out-of-hospital cardiac arrest. Experience in children is more limited. Six paediatric studies (LOE 5)219–222 show that prolonged resuscitation is associated with a poor outcome. Although the likelihood of a good outcome is greater with a short duration of CPR, two paediatric studies (LOE 3)223,224 reported good outcomes in some patients following 30–60 min of CPR in the in-patient setting when the arrests were witnessed and prompt and presumably excellent CPR was provided. Children with cardiac arrest associated with environmental hypothermia or immersion in icy water can have excellent outcomes despite >30 min of cardiac arrest (LOE 5).225,226
References


Appendix A. Supplementary data


References


84 Part 6: Paediatric basic and advanced life support

79. Engoren M, Plewa MC, Buderer NF, Hymel G, Brookfield
78. Berg RA, Kern KB, Hilwig RW, Ewy GA. Assisted ventila-
76. Berg RA, Wilcoxson D, Hilwig RW, et al. The need for ven-
73. Bossaert L, Van Hoeyweghen R, The CerebralResuscita-
69. Christensen DW, Jansen P, Perkin RM. Outcome and acute
68. Suominen P, Rasanen J, Kivioja A. Efficacy of car-
65. Berg RA, Hilwig RW, Kern KB, Babar I, Ewy GA. Simu-
infarction model does not improve outcome. Circul ation
rescuer bystander cardiopulmonary resuscitation. Ann Emerg Med
1989;17(Suppl.):S55—69.
Efficacy and safety of intravenous Amiodarone in infants and
A multicentre, randomized, double-blind, placebo-
Intravenously administered dofetilide versus amiodarone
in the acute termination of atrial fibrillation and flut-
er. A multicentre, randomized, double-blind, placebo-
Burr S, Hug M, Baurofeld U. Efficacy and safety of intra-
80. Wen ZC, Chen SA, Tai CT, Chiang CE, Chiuw CW, Chang
86. Waxman MB, Wald RW, Sharma AD, Huerta F, Cameron DA. Vagal techniques for termination of paroxysmal supraven-
85. Josephson ME, Selkis SE, Batsford AB, Caracta AR, Dam-
84. Lim SH, Anantharaman V, Too WS, Goh PP, Tan AT. Com-
83. Figa FH, Gow RM, Hamilton RM, Freedom RM. Clinical effi-
cacy and safety of intravenous Amiodarone in infants and
infarction model does not improve outcome. Circul ation
Becker LB, Berg RA, Pepe PE, et al. A reappraisal of mouth-
to-mouth ventilation during bystander-initiated cardiopl-
monary resuscitation. A statement for healthcare profes-
sionals from the Ventilation Working Group of the Basic Life Support and Pediatric Life Support Subcommittees, Amer-
Suominen P, Rasanen J, Kivioja A. Efficacy of car-
Christensen DW, Jansen P, Perkin RM. Outcome and acute care hospital costs after warm water near drowning in chil-
Young KD, Seidel JS. Pediatric cardiopulmonary resuscita-
Waalwijl RA, Tijssen JG, Koster RW. Bystander initi-
ated actions in out of hospital cardiopulmonary resuscita-
Holmberg M, Holmberg S, Herlitz J. Factors modifying the
effect of bystander cardiopulmonary resuscitation on sur-
Bossaert L, Van Hoeveeghen R, The Cerebral Resusci-
tion Study Group. Bystander cardiopulmonary resuscita-
Berg RA, Wilcoxson D, Hovind RW, et al. The need for ven-
Berg RA, Kern KB, Hillwig RW et al. Assisted ventilation does not improve outcome in a porcine model of single-
rescuer bystander cardiopulmonary resuscitation. Circula-
tion 1997;95:1635—41.
Berg RA, Kern KB, Hillwig RW, Ewy GA. Assisted ventila-
Eyergeren AF, Pluym MC, Buderer NF, Hynel G, Brookfield L. Effects of simulated mouth-to-mouth ventilation dur-
90. Craig JE, Scholz TA, Vanderhoof SL, Etheridge SP. Fat necrosis after ice application for supraventricular tachy-
91. Thomas WD, Torres A, Garcia-Polo J, Gavlani C. Life-
92. Bianconi L, Castro A, Dinelli M, et al. Comparison of intravenously administered dofetilide versus amiodarone in the acute termination of atrial fibrillation and flut-
er. A multicentre, randomized, double-blind, placebo-
93. Burri S, Hug M, Baurofeld U. Efficacy and safety of intra-
94. Cabrera Duro A, Rodrigo Carbonero D, Galdeano Mirand a J, et al. The treatment of postoperative junctional ectopic tachycardia, Spanish. Anales Espanoles de Pedia-
Figa FH, Gow RM, Hamilton RA, Freedman R. Clinical effi-
Laird WP, Snyder CS, Kertesz NJ, Friedman RA, Miller D, Fenrich AL. Use of intravenous amiodarone for postoper-


255. Albrecht IInd RF, Wass CT, Lanier WL. Occurrence of hyperthermia after perinatal asphyxia (35.0 degrees C and 34.5 degrees C) after perinatal asphyxia. Pediatrics 2003;111:244–51.

256. Battin MR, Penrice J, Gunn TR, Gunn AJ. Treatment of term infants with head cooling and mild systemic hypothermia (35.0 degrees C to 34.5 degrees C) after perinatal asphyxia. Pediatrics 2003;111:244–51.


283. Hickory RK, Kochanek PM, Farinheimer H, Alexander HL, Garan-}

matis HH. Graham hypersensitivity: a rare case of allergic reaction to

284. D’Alecy LG, Lundy EF, Barton KJ, Zelenock GB. Dextrose in
cardiac surgical patients with left-ventricular dysfunction. A prosp-}

285. Kikura M, Sato S. The efficacy of preemptive Milrinone or
tents].

286. Calle PA. Buyaert VA, Vanhaute OA. Glycemia in the post-}


288. Rivers EP, Wortsman J, Rady MY, Blake HC, McGeorge FT,
Checchia PA, Sehra R, Moynihan J, Daher N, Tang W, Melosch T. Long-lasting

neurological outcome in rats following cardiac arrest and attenua-

290. Laitinen P, Inui TS, High blood glucose level on hospital-

291. Weil MH. Myocardial injury in children following resus-

292. Buderer NM. The effect of the total cumulative epinephrine
dose administered during human CPR on hemodynamic, oxygen transport, and utilization variables in the post-}

neurological outcome in rats following cardiac arrest and attenua-

neurological outcome in rats following cardiac arrest and attenua-

neurological outcome in rats following cardiac arrest and attenua-